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MYSTERIES: Paralleling Generators – When Two Perfect Machines Refused to Share

12 March 2026

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Emeritus Professor Akhtar Kalam

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Introduction – Presenter

Emeritus Professor Akhtar Kalam

Emeritus Professor at Victoria University and EIT.
Academic Director and Chair of the Academic Board - Texila College Australia.
Director of Al-Kalam Educational Solutions.
Editor-in-Chief of AJEEE
Distinguished Professor/Adjunct Faculty in Australia, India, Malaysia and Oman.
He has published over 610 publications in his area of expertise and has written over 29 books.
Supervised 51 postgraduate research students to graduation, including 39 PhD's and 12 MEngs. Currently, 10 postgraduate research students (four PhD students at VU and six DEng students at EIT) are being supervised.
Public, University, and Motivational Lecturer.
Consultant for the electricity supply industries in Australia and overseas.
Assisted in change management plans for Universities and the higher education sector.

Education

The University of Bath, Bath, UK, D.Eng., Electrical Engineering
The University of Oklahoma, Norman, USA, MS, Electrical Engineering
Aligarh Muslim University, Aligarh, India, BSc. Eng., Electrical Engineering
St Xavier's College, Calcutta, India, Applied Science

Professional Society Activities

Australian Institute of Energy – Fellow
Engineers Australia – Fellow
The Institution of Engineers and Technology, UK – Fellow.
The Institution of Electrical and Electronic Engineers, USA –Life Senior Member.

"My vision is to provide exciting higher education science and engineering courses, research, consultancy and collaborate in development work of the industry and communities within Australia and beyond."

Agenda

	Learning Objectives
	Introducing the Case
	The Critical Question
	Why Night-time matters?
	Why did Protection not operate?
	Key Technical Lessons
	Key Takeaways
	Q&A

Preliminaries

Learning Objectives

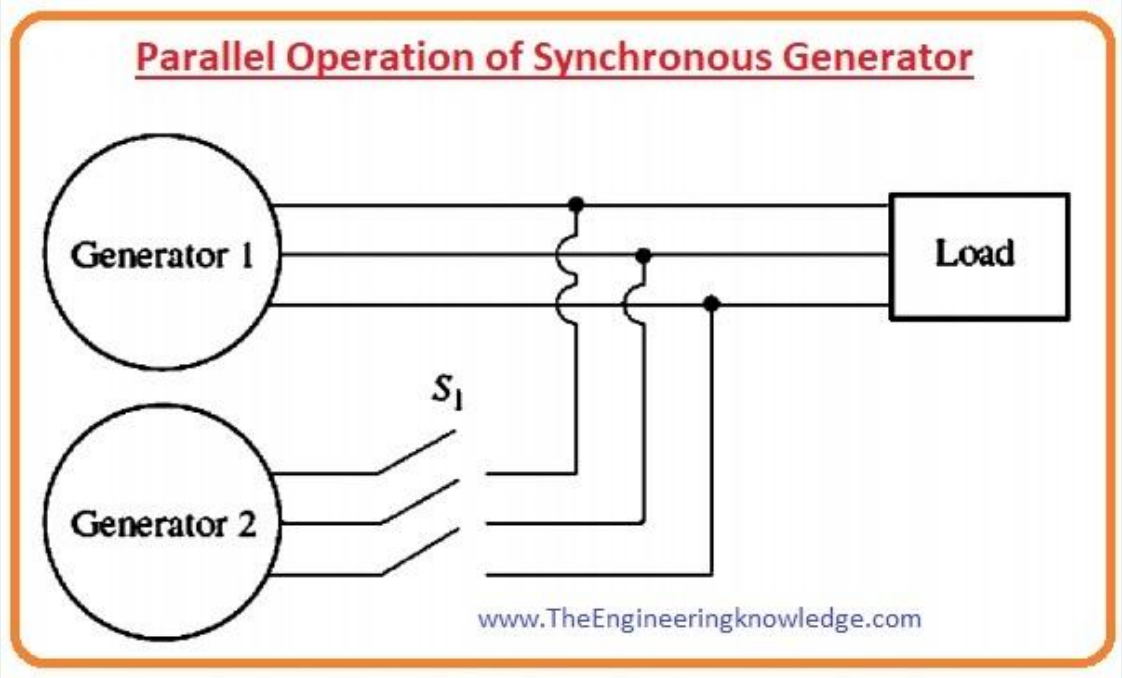
- Parallel Operation of DC Generators Definition: Parallel operation involves connecting multiple DC generators to provide a continuous, reliable power supply.
- Bus-Bar Connection: Generators are connected in parallel using bus bars, with the positive and negative terminals properly aligned.
- Load Sharing: By adjusting the induced emf, multiple generators can share the electrical load evenly.

Why This Story Matters

- Generator paralleling is a “solved theory”.
- Yet failures occur in modern plants.
- Real systems expose gaps between math and reality.
- Postgraduate engineers must think beyond equations.

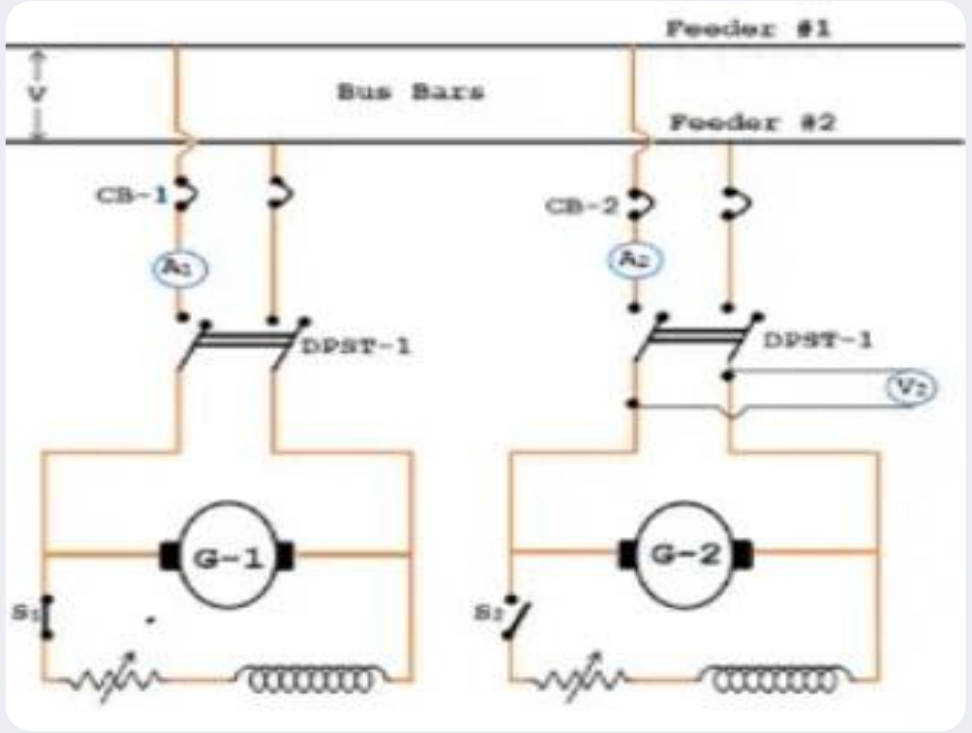
The Setup: Two “Perfect” Machines

- Two synchronous generators
- Same rating, same manufacturer
- Identical governors and exciters
- Recently commissioned system
- Intended for parallel operation.



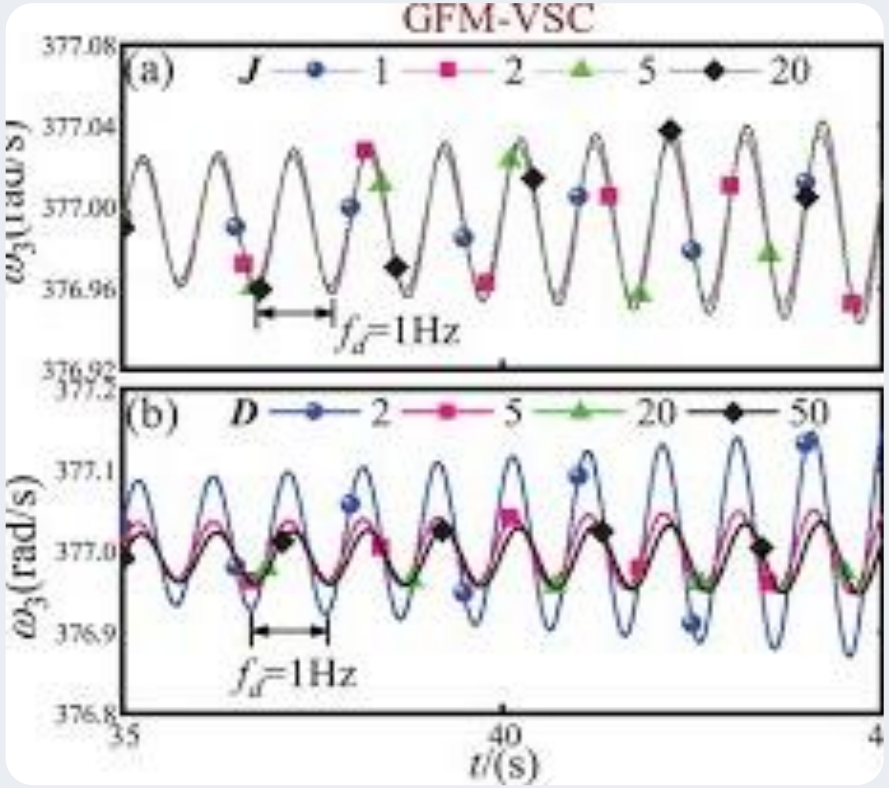
The Expected Behaviour

- Synchronise voltage, frequency, phase
- Close breaker
- Increase prime mover input
- The load should be divided proportionally
- Stable operation



Introducing the Case

- Synchronisation successful
- Breaker closed cleanly
- One generator took nearly all the real power
- The other “floated” near zero
- Adjustments made things worse.

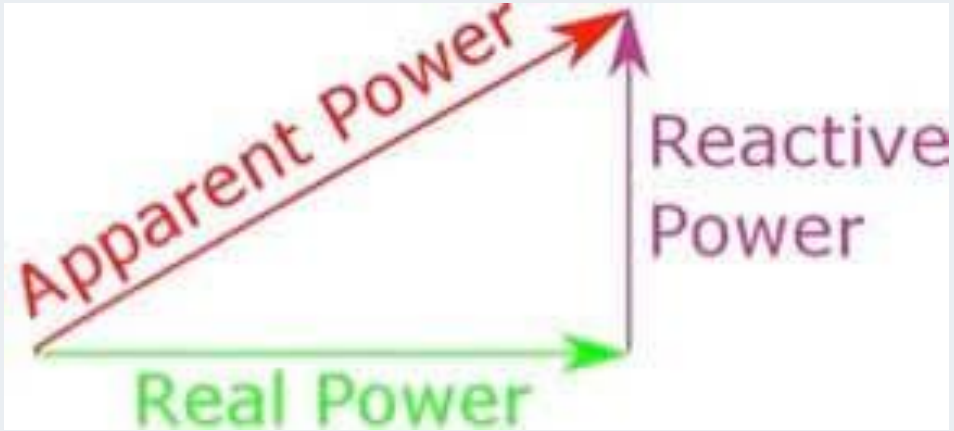


First Reactions

- “Faulty generator?”
- “Bad governor tuning?”
- “Incorrect wiring?”
- “Instrumentation error?”
- “Operator mistake?”

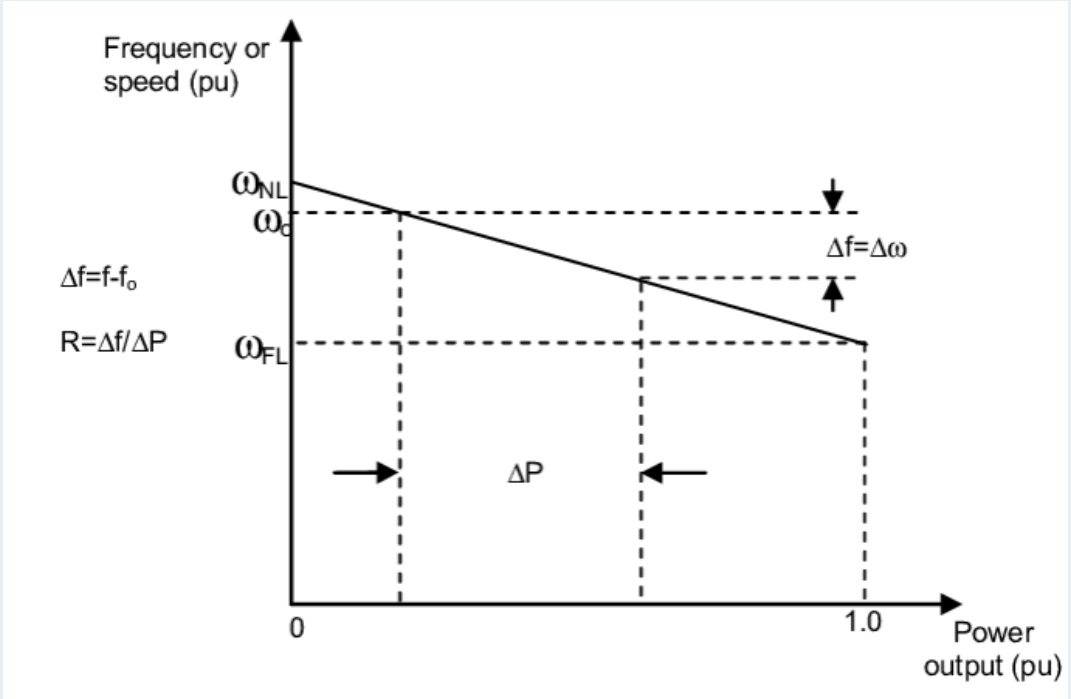
Theory Refresher: Real vs Reactive Power

- Real power (kW): controlled by prime mover/governor
- Reactive power (kVAr): controlled by excitation
- Sharing depends on control characteristics
- Identical ratings ≠ identical behaviour



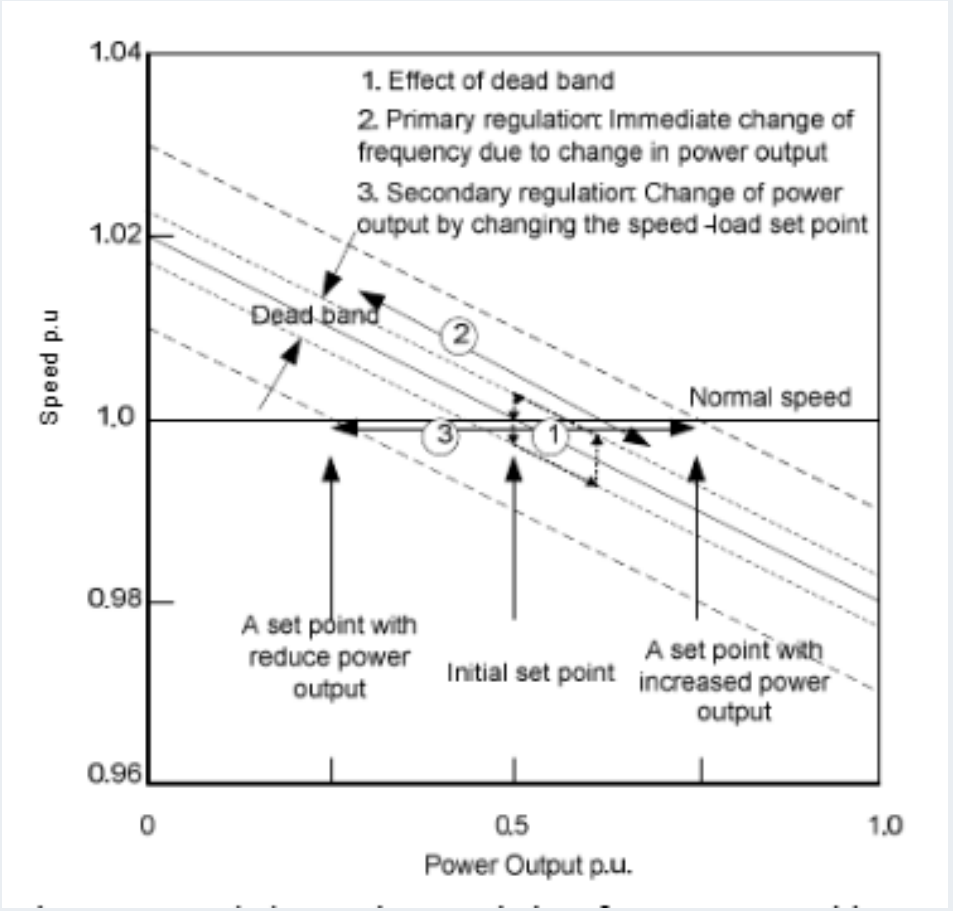
Governor Control Basics

- Governors regulate speed (frequency)
- Droop characteristic enables load sharing
- Without droop → instability
- Matching droop slopes is essential



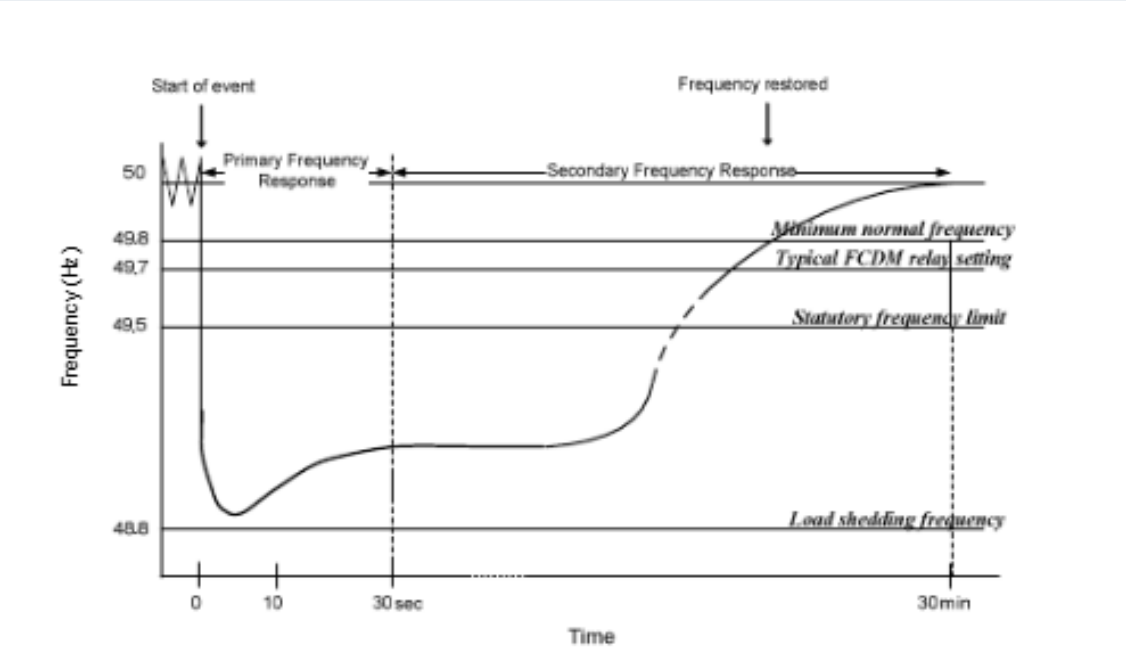
The Hidden Assumption

- Assumed both governors had identical droop
- Assumed factory settings were equal
- Assumed “same model” = “same response”
- No direct droop verification performed



Field Measurements Begin

- Frequency vs power measured
- Load ramp tests performed
- Individual generator response recorded
- Small discrepancies observed

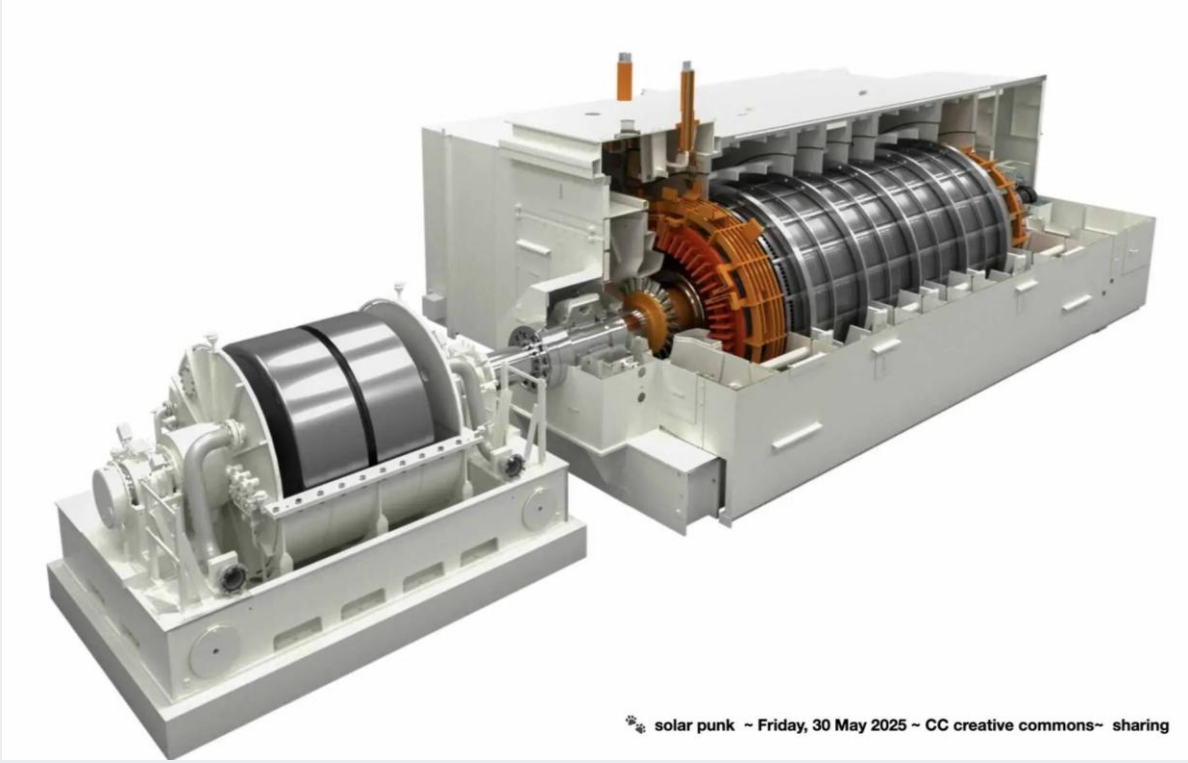


The Critical Discovery

- Generator A droop: ~4%
- Generator B droop: ~1%
- Both “within acceptable range”
- But not compatible for sharing

Why One Generator Dominated

- Lower droop = stiffer speed control
- A stiffer machine resists frequency change
- It absorbs most real power changes
- The other machine backs off

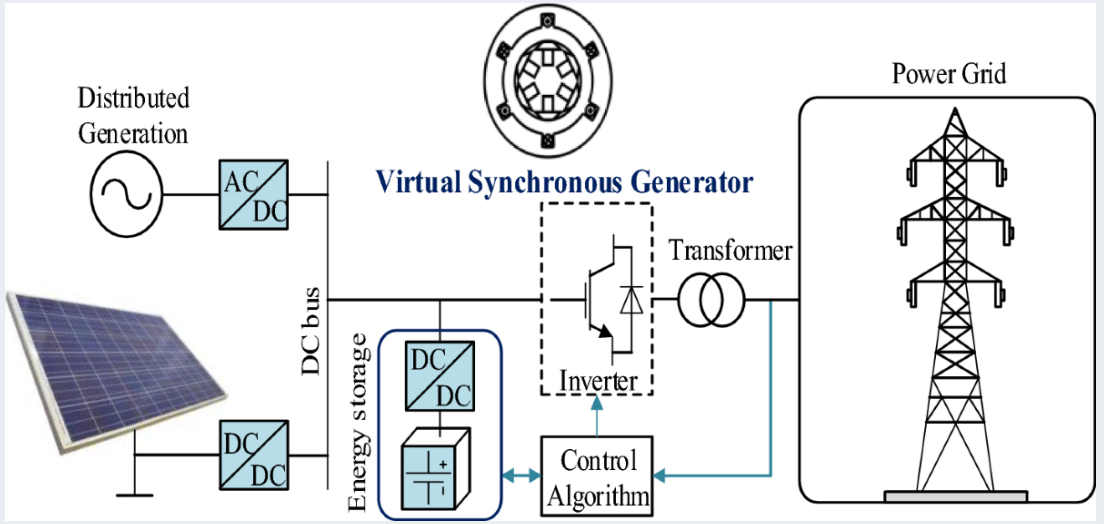


Why Adjusting Speed Didn’t Help

- Speed bias shifts operating point
- Does not change droop slope
- Temporary improvement only
- Instability increased under load

What About Reactive Power?

- Reactive power sharing also problematic
- Exciters set to voltage control mode
- No VAr droop enabled
- Circulating reactive currents observed

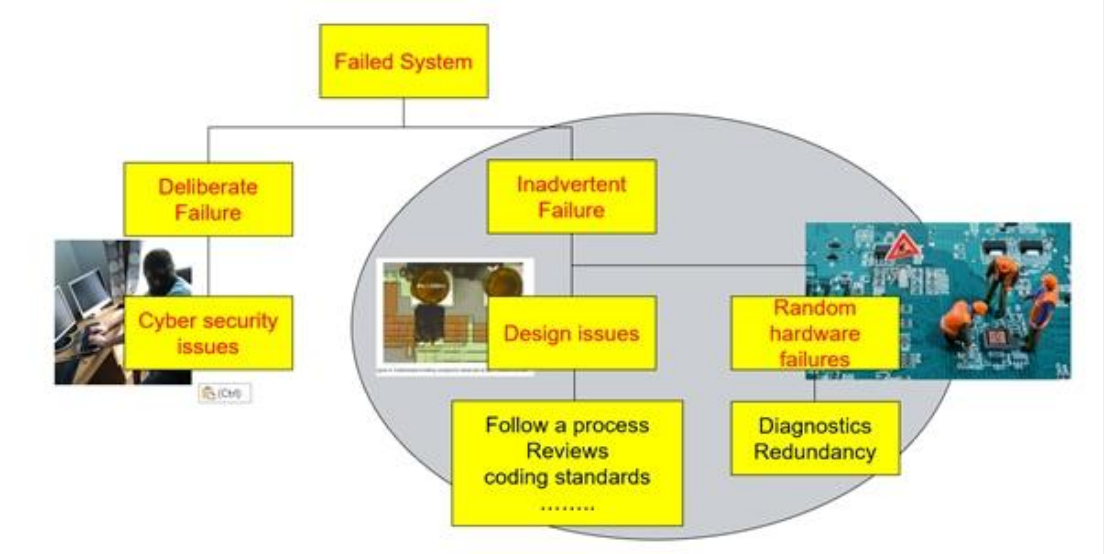


Circulating Currents Explained

- Small voltage differences → large reactive currents
- No useful load delivered
- Increased heating
- Reduced system stability

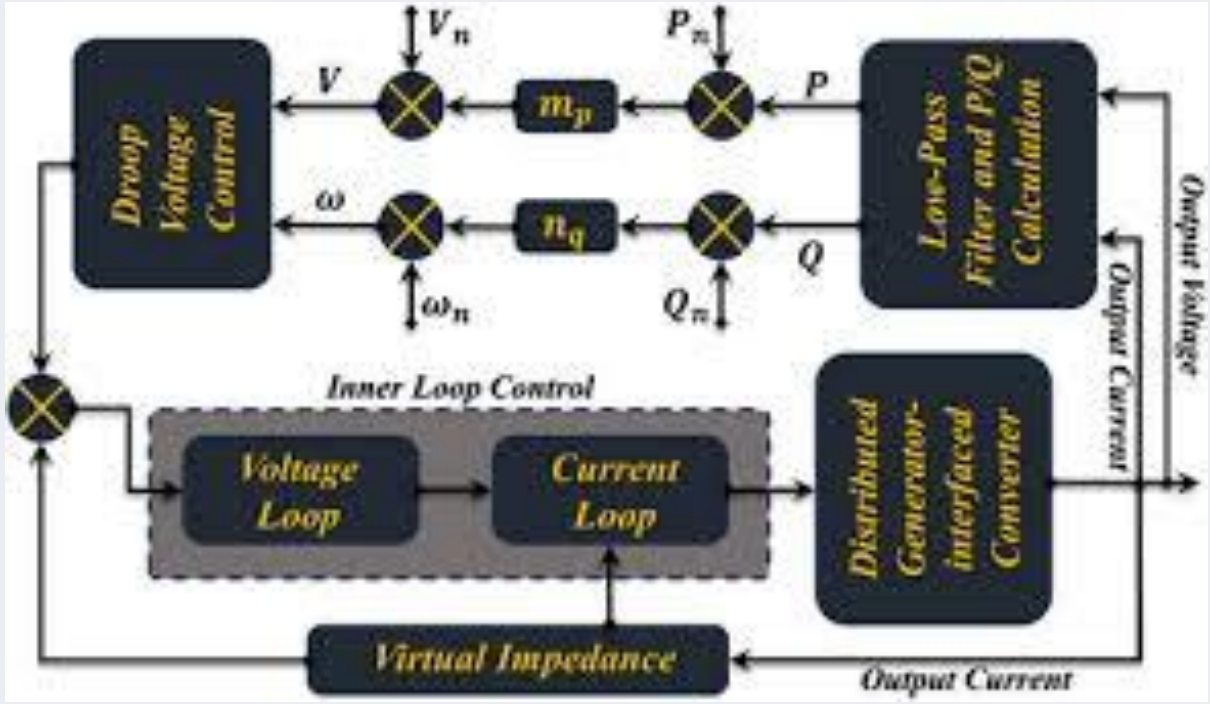
The Root Cause (Summarised)

- Mismatched governor droop
- No coordinated control philosophy
- Overreliance on factory defaults
- Lack of system-level testing



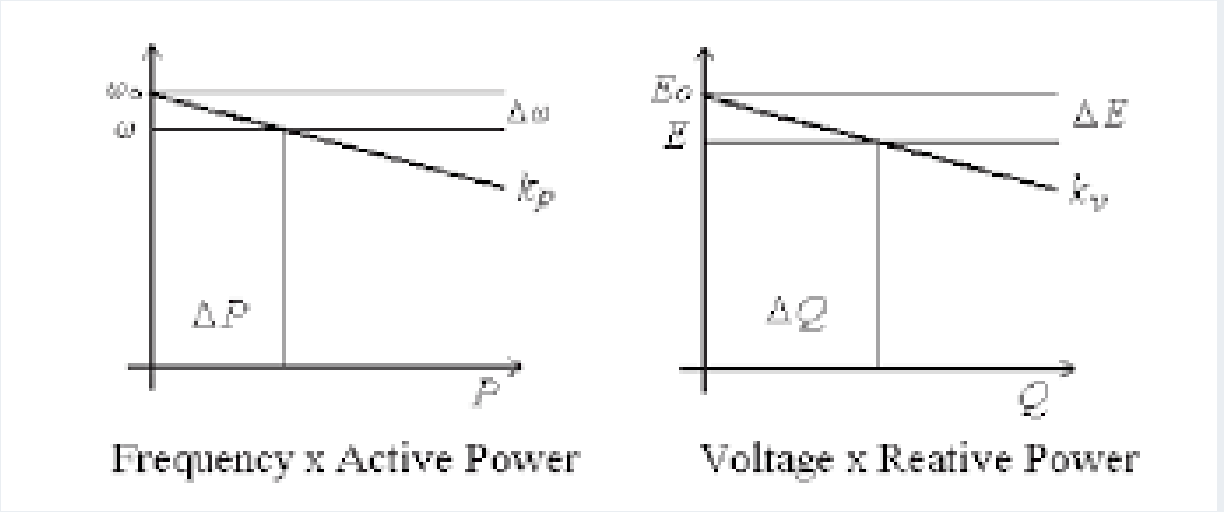
The Fix: Real Power Sharing

- Standardised droop settings
- Verified frequency–power slopes
- Re-tested under dynamic load
- Stable proportional sharing achieved



The Fix: Reactive Power Sharing

- Enabled voltage droop (or VAr control)
- Coordinated excitation settings
- Reduced circulating currents
- Thermal margins restored



Frequency x Active Power

Voltage x Reative Power

Why This Happens So Often

- Commissioning under no-load conditions
- Control systems tested in isolation
- “Within tolerance” thinking
- Missing interdisciplinary oversight

Textbook vs Field Reality

- Textbooks assume idealized controls
- Real systems include tolerances
- Control interactions dominate behaviour
- Measurements matter more than labels

Broader Lesson: Perfection Can Be the Enemy

- Overly tight control causes conflict
- Intentional flexibility improves stability
- Droop is a feature, not a defect
- Cooperation beats precision

Similar Mysteries in Power Engineering

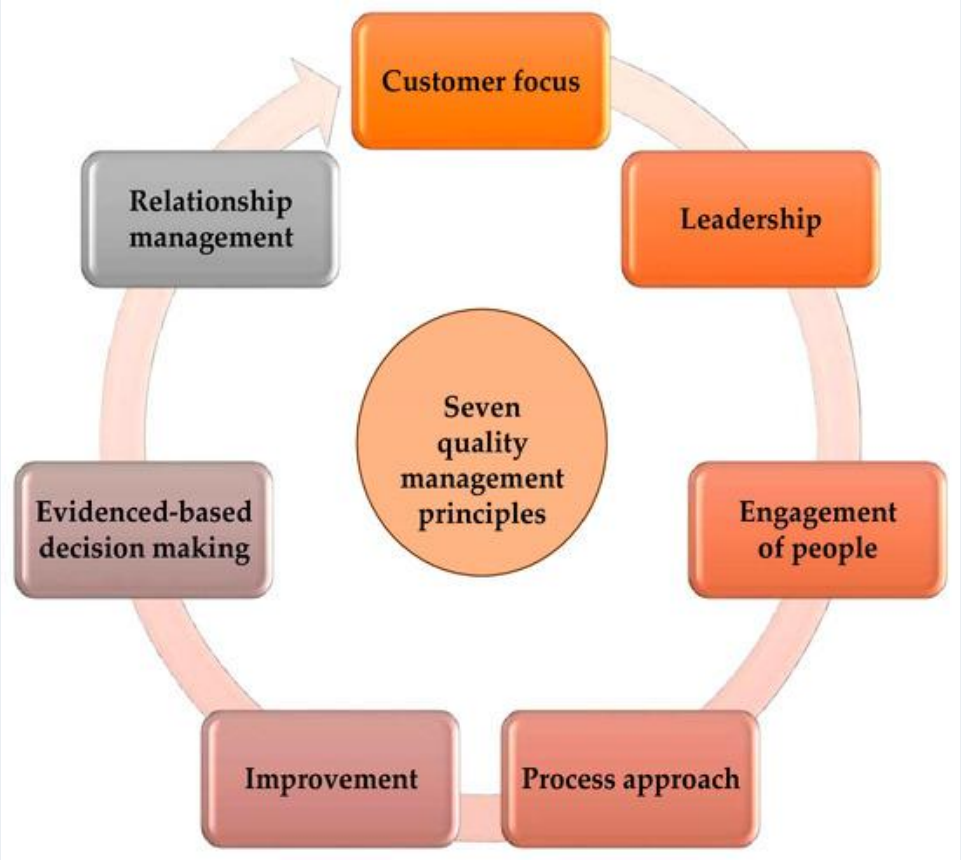
- UPS systems that won’t share
- Parallel inverters oscillating
- Microgrids with unstable islands
- Wind turbines fighting frequency

What Postgraduate Engineers Must Remember

- Controls define behaviour
- Matching ratings is not enough
- Measure dynamic response
- Always ask: “What assumption am I making?”

Discussion

- How would this change with three generators?
- What if one were inverter-based?
- Would isochronous control help?
- Where would you instrument first?



Key Takeaways

- Generator paralleling is a control problem
- Droop enables cooperation
- “Identical” machines are never identical
- System thinking beats component thinking

Why This Is a Mystery Worth Remembering

- Simple problem, complex cause
- No alarms, no obvious faults
- Required engineering judgment
- A lesson learned once—never forgotten

Closing Thought

“Engineering Is Not About Perfect Parts;
It’s About Cooperative Systems.”

Q&A

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